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Original article

Natural enemies feeding on some *Centaurea* species in the Yüksekova basin

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ABSTRACT

Background: Excessive and unconscious use of pesticides in agricultural areas negatively affects ecosystem services and biodiversity and threatens human and environmental health. Therefore, natural enemies (biological control agents) that could be utilized to suppress the infestation of diseases, pests and weeds have attracted the attention of scientists globally. There are limited studies on the occurrence of natural enemies on *Centaurea* species in the Yüksekova basin, Turkey. The Yuksekova basin has a rich floristic diversity; however, remained unexplored and underutilized. Limited use of pesticides, and the presence of natural enemies feeding on weeds in the region have recently attracted the attention of researchers for searching biological control agents. Asteraceae is the dominant family in the region with the highest diversity, causing significant yield losses in agricultural area of the basin.
Methods: Therefore, preliminary studies were conducted to determine the natural enemies feeding on the genus *Centaurea*. The region was divided into 10 × 10 cm systematic grids and occurrence of *Centaurea* species, and their natural enemies were recorded.
Results: The survey identified 10 species belonging to *Centaurea* genus in the study area. Different insect species, i.e., *Lixus pulverulentus* Scopoli, *Larinus grisescens* Gyllenhal and *Bangasternus orientalis* Capiomont belonging to Curculionidae (Coleoptera) family were observed to feed and spend biological periods on *Centaurea behen* L., *Centaurea pterocaula* Trautv. and *Centaurea iberica* Trev. ex Spreng species.
Conclusions: It is estimated that the natural enemies recorded on *Centaurea* species could be potentially used in biological control of the species on which they were recorded in the current study. However, detailed studies on host specificity and efficacy of the identified insect species are needed.

1. Introduction

Several biotic and abiotic factors such as humans, animals, and plant protection factors in addition climate and soil significantly alter crop production. Rapid climate changes have made weed infestations more important, as uncontrolled large weed populations cause serious yield and economic losses (Önen and Özcan, 2010). Weeds cause massive economic losses in agricultural areas, since they compete with cultivated plants for light, water, nutrients and space, host harmful microorganisms and disrupt agricultural activities (Özer et al., 2001). Yield losses due to weeds vary depending on crop species and prevailing ecological conditions, and may reach ~90% (Önen et al., 1997). For this reason, it is estimated that weeds cause ~150 billion dollars' losses annually in agricultural production at global level (Döken et al., 2000).

Weed management has been initiates with the beginning of agriculture and continues till today. Hand pulling, and crop rotation were the primitive methods of weed control at the start of agriculture. However, mechanical and physical management methods were started with industrial development and mechanization. In the later period, especially after World War II, weed

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management witnessed a golden period since most of the herbicides were developed and utilized for weed management in this era. Unfortunately, herbicides have resulted in the evolution of resistance in numerous weed species and posed serious negative impacts on environment and human health. For this reason, farmers have started to avoid chemical control and directed towards biological control. Biological control is harmless to natural and biological diversity and could serve as alternative to herbicides (Delen and Tosun, 1997).

Excessive and unconscious use of herbicides in the recent years had imposed severe negative impacts on human health, food safety and ecosystem. Therefore, biological control of weeds has emerged as one of the best alternative methods to chemical control (Uygun et al., 2010). Biological control is based on the deliberate use of target-specific natural enemies to control weeds. The use of biological control has increased rapidly around the world, especially in meadow-pastures and agricultural areas. Biological control is one of the most effective methods in the control of invasive species that cause significant ecological and economic problems. Biological control is the reinforcement, protection, and support of natural enemies that directly or indirectly damage or weaken the host weed species, without harming the cultivated plants (DeBach, 1964; Atay et al., 2015).

More than 200 weed species are controlled by ~500 natural enemies in >90 countries, including the USA, Canada, Australia, New Zealand, and South Africa, which are top users in exploiting natural enemies for weed management globally (Day and Witt, 2019). Biological control agents generally consist of insects, microbial agents (fungi, bacteria, and viruses) and polyphagous organisms (mammals, fish, geese, snails, etc.) (Uygun et al., 2010; Atay et al., 2015).

Biological control studies against weeds in Turkey have generally been limited to the detection of natural enemies. The first studies on biological control of *Centaurea* species in the country were conducted Cristofaro et al (2002). Field studies were carried out to detect harmful insect species feeding on *Centaurea solstitialis* L. and quantify their damages. Afterwards, studies were conducted to determine population densities for biological control of *C. solstitialis* in the Eastern Mediterranean region (Uygur et al., 2004; Uygur et al., 2012).

The Asteraceae family is one of the richest families in the world in terms of species' diversity. Most of the Asteraceae species are cosmopolitan (Attard and Cuschieri, 2009). Similarly, the Asteraceae is one of the families with the highest number of flowering plant species in the local flora in Turkey, especially in agricultural areas (Güner et al., 2012). More importantly, Turkey is one of the main centers of *Centaurea* species' diversity (Wagenitz, 1986). Globally, there are >700 plant species belonging to the genus *Centaurea* (Bensouici et al., 2012) and 205 of them are in the flora of Turkey (Şirin et al., 2020). Of the 700 species, 125 are endemic (Güner et al., 2012; Uysal 2012; Bancheva et al. 2014; Uysal et al. 2015). The local flora of Hakkari province includes 26 *Centaurea* species, of which 5 are endemic (Güner et al., 2012).

The aim of this study was to pre-screen the *Curcullonidae* species feeding on the leaves, stems, and seeds of *C. behen*, *C. pterocaula* and *C. iberica*, which have established populations in the Hakkari region.

2. Materials and methods

The study was carried out in Gever plain situated at altitude of 1950 in Hakkari/Yüksekova district of Eastern Anatolia Region, Turkey during 2020. The study area is located between 37.427253° N – 37.598928° N latitudes and 44.071683° E – 44.423028° E longitudes.

The study region is rich in biodiversity, and ecological balance and limited use of pesticides increases the chances of occurrence of biological control agents. *Centaurea* belonging to the Asteraceae family causes important problems, especially in agricultural areas in Turkey and the world. Therefore, pre-screening of the diversity, density and natural enemies feeding on different species of the genus was conducted in this study.

Centaurea species were observed in agricultural areas, meadow-pastures and roadsides to find out the biological control agents feeding on them. In the study, observations were made at 20 points separated by 1 km distance (including intermediate transect points) based on the main and intermediate roads in the region. In addition, *Centaurea* species were examined in an area of 20 × 20 square meters at each sampling point. Adults and larvae feeding on plants were collected, cultured, and identified in the laboratory. The locations of the natural enemies detected on *Centaurea* species are given in Fig. 1.

3. Results and discussion

In the survey, 10 species belonging to the *Centaurea* genus were identified. The scientific name, Turkish name, phytogeographic region, origin, density, and frequency of occurrence of these plants are given in Table 1. The *C. iberica* (47.91%), *C. pterocaula* (33.73%) and *C. behen* (12.54%) were the most common dense species in the surveyed region. However, the most abundant and densely distributed species in agricultural areas in the region were *C. iberica* and *C. pterocaula*.

The insect species directly feeding on the host species and causing damage were recorded in surveys. For this purpose, areas with frequent distribution of *Centaurea* species were surveyed in different periods. In the study, 3 insect species belonging to Curculionidae family were found feeding on Centaurea species, caused visible damage and spent their biological stages. The information on the detected host weed species and insects feeding on them are summarized below.

3.1. Host species: Centaurea behen L.

The *C. behen* is naturally distributed between altitudes of 340–1950 m. Generally, the speices is distributed in agricultural areas, fallow lands, meadow-pasture, rocky slopes, barren lands, and roadsides in the surveyed region (Davis, 1975; Özaslan, 2011; Ateş, 2019).

3.2. Morphological characteristics

The *C. behen* is perennial with erect glabrous stems. Its height can vary between 60 and 150 cm, and branches exceed the main axis with several capitulas from above. The leaves are hard and veins are fluffy and hairless. Although the leaf shapes vary according to the location, they can be generally lanceolate, oblong, broad-lanceolate or ovate-lanceolate. The length of the lower leaves is 10–13 cm, width is 6–10 cm, length of the middle leaves is 5–6 cm, and width is 1.5–2.5 cm. The flowering period is usually in June-August, and the flowers are yellow, with achenes exceeding 5 mm and pappus 5–8 mm (Ateş, 2019; Anonymous, 2021c).

3.3. Natural enemies: Lixus pulverulentus Scopoli (Coleoptera: Curculionidae)

Distribution in the world: Western Palaearctic and central Asia (Dieckmann, 1983). Alonso-Zarazaga (2008) clearly shows the synonymy: *Lixus pulverulentus* [= *L. angustatus* (Fabricius, 1775)]. Albania, Austria, Bulgaria, Cyprus, France, Georgia, Germany, Greece,

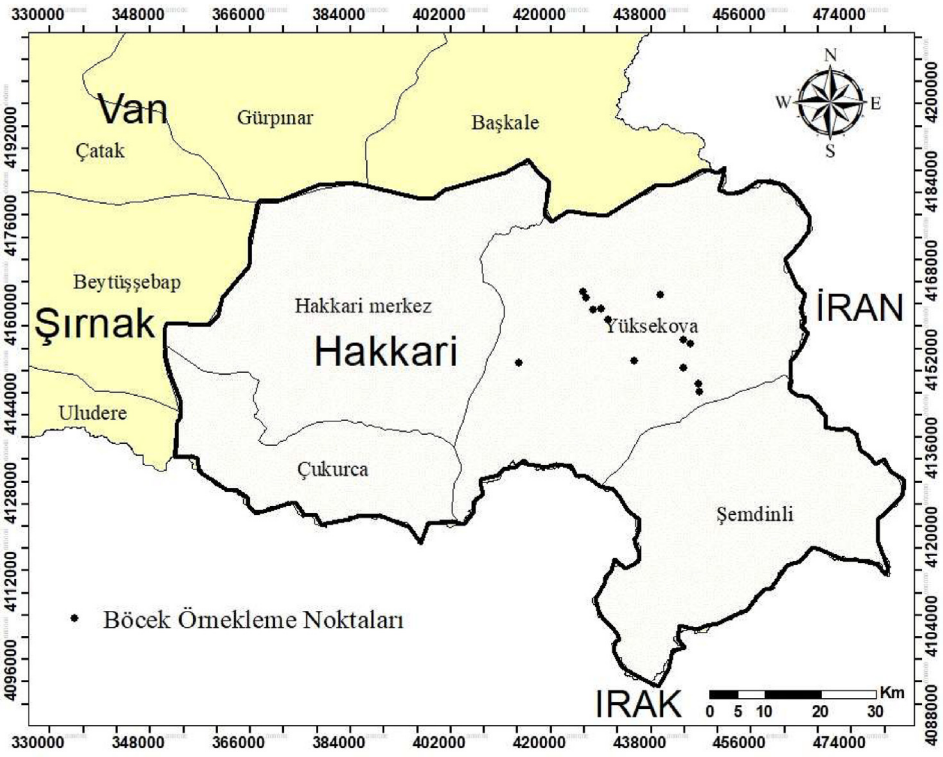

Fig. 1. Locations of natural enemies feeding on *Centaurea* species in Yüksekova Basin.

Table 1
Latin and local names, phytogeographic region, origin, density, and frequency of occurrence of *Centaurea* species detected in Yüksekova Basin.

Latin name	Turkish name	Phytogeographic region	Origin	Density (plant m^{-2})	Frequency of occurrence (%)
Asteraceae					
Centaurea behen L.	Zerdalidikeni	Iran-Turan elements		1,01	12,54
Centaurea carduiformis DC. subsp. *carduiformis* var. *carduiformis*	Kavgalaz			0,67	1,27
Centaurea gigantea subsp. Gigantea	Daldakdikeni			1,50	0,90
Centaurea glastifolia L.	Kotankıran	Iran-Turan elements		1,00	0,69
Centaurea iberica Trev. ex Spreng.	Deligözdikeni		Africa, Europe, Asia	1,60	47,91
Centaurea nemecii Nábělek	Delikavgalaz	Iran-Turan elements		0,95	5,93
Centaurea persica Boiss.	Acemkavgalazı	Iran-Turan elements		1,00	0,95
Centaurea pterocaula Trautv.	Çoruşbozan	Iran-Turan elements		1,17	33,73
Centaurea solstitialis subsp. solstitialis L.	Çakırdikeni	Iran-Turan elements	Cosmopolit	1,00	0,95
Centaurea virgata Lam.	Acısüpürge	Iran-Turan elements	Africa, Europe, Asia	1,00	1,64

Hungary, Moldova, Netherlands, Romania, Slovakia, Syria, Turkey, Ukraine (Anonymous, 2021b).

Distribution in Turkey: Hatay-Antakya [Lodos et al. (2003) referred to it as sub-*L. algirus* (Linnaeus, 1758)] and Osmaniye (Pehlivan et al., 2005).

Material examined: Yüksekova basin Latitude-Longitude: 429149D-4159086K, 427603D-4158940K, 425838D-4162250K, 439750D-4161692K, 445231D-4152902K, 414378D-4149438K, 434989D-4149786K altitude, 1866–1950 m.

Recorded hosts: Malvaceae, Asteraceae, and Fabaceae (*Alcea rosea, Malva pusilla, Malva sylvestris. Malva thuringiaca. Cirsium arvense, Cirsium palustre, Cirsium serrulatum, Carduus acanthoides, Silybum marianum, Centaurea nigra, Onopordum acanthium, Vicia faba* (Dieckmann, 1983; Boukhris-Bouhachem et al., 2016; Arzanov, 2017; Anonymous, 2021b) (Fig. 2).

New host record: In the present study, *Centaurea behen* was recorded as a new host of *Lixus pulverulentus* from Hakkari/Turkey for he first time in the world (Fig. 2).

3.4. Larinus grisescens Gyllenhal (Coleoptera: Curculionidae)

Distribution in the world: Bullgaria, Central Asia, Greece, Israel, Italy, Kazakhstan, Montenegro, North Africa, North Macedonia, Russia, Serbia, Southern Europe, Syria, Transcaucasia and Turkey.

Distribution in Turkey: Adana, Adıyaman, Artvin, Bingöl, Bitlis, Diyarbakır, Elazığ, Erzurum, Erzincan, Gaziantep, Hatay, Iğdır, Kars, Kırıkkale, Kilis, Malatya, Nevşehir, Osmaniye, Sivas and Şanlıurfa (Özgen et al., 2016; Gültekin, 2006) (Fig. 3).Fig. 4..

Material examined: Yüksekova basin Latitude-Longitude: 445231D-4152902K, 429149D-4159086K, 429149D-4159086K, 425838D-4162250K, altitude, 1866–1950m.

Recorded hosts: *Carthamus tinctorius* L. (Asteraceae), *Astragalus cephalanthus* Dc. (Fabaceae) (Abad et al., 2016), *Carthamus oxyacantha* M. Bieb. (Asteraceae) (Shahriyari-Nejad et al., 2013), *Carduus* spp. (Asteraceae) (Özgen et al., 2016) (Fig. 3).

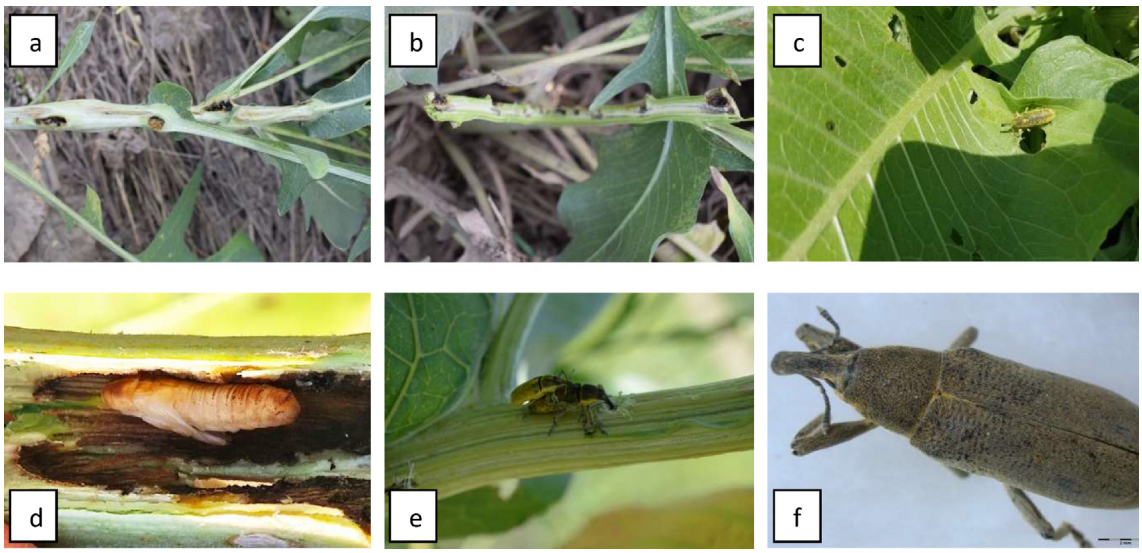

Fig. 2. *Centaurea behen* (a,b,c) infested with the larvae of *Lixus pulverulentus* (d,e,f).

Fig. 3. *Centaurea behen* (a) infested with the larvae of *Larinus grisescens* (b,c).

Fig. 4. *Centaurea ptercaula* (a) infested with the larvae of *Larinus grisescens* (b,c).

New host record: In the present study, *Centaurea behen* was recorded as a new host of *Larinus grisescens* from Hakkari/Turkey for he first time in the world (Fig. 3).

Host species: *Centaurea pterocaula* Trautv. (Asteraceae).

The *C. ptercaula* generally spreads in agricultural areas, meadows, dry slopes, empty lands, and roadsides in the region. Its natural distribution areas are between 900 and 2400 m (Tugay et al., 2006).

3.5. Morphological characteristics

The *C. ptercaula* is a perennial with an erect stem, branches towards the top and can reach to 2 m in height. The leaves generally change according to their location, the base and lower leaves are petiolate, 4–5 cm, the middle and upper leaves are sessile. The leaf form gradually narrows towards the upper part. The flowering period is between July and August, and the color of the flowers is yellow, achenes 6 mm, pappus 6–11 mm (Davis et al., 1988; Tugay et al., 2006).

Material examined: Yüksekova basin Latitude-Longitude: 443906D-4148512K, 443844D-4153660K, 429149D-4159086K altitude, 1866–1950m.

Natural enemies: *Larinus grisescens* Gyllenhal (Coleoptera: Curculionidae).

Host species: *Centaurea iberica* Trev. ex Spreng. (Asteraceae).

It has been stated that the general distribution of *C. iberica* is in natural areas, agricultural areas, water and roadsides, waste areas and pasture areas (Tadmor et al., 1974; Wagenitz, 1975; Keil and Ochsmann, 2006; DiTomaso and Healy, 2007). However, Nasir and Sultan (2006) reported that *C. iberica* is one of the three most important weeds in the mustard fields in the Chakwal Region of Pakistan. It ranks seventh in the general weed ranking in the region. In the studies carried out in the region, it has been determined that the plant is found in similar areas and is one of the most common weeds.

Fig. 5. *Centaurea iberica* Trev. ex Spreng. (a, b), *Bangasternus orientalis* (Capiomont, 1873) (c).

3.6. Morphological characteristics

Although *C. iberica* has a widespread distribution (about 2300 m), germination, rosette formation and flowering periods vary depending on ecological factors. It usually blooms in May-July and the flower color is seen as pale pink (Whitson et al., 1996). The plant can be an annual, biennial, or short-lived perennial (Keil and Ochsmann, 2006). It usually grows in a forum that can grow up to 68–96 cm in length and starts at the bottom and branches repeatedly. Its leaves are sparsely hairy, and their leaf length varies between 2 and 11 cm and width 2–4 cm (DiTomaso and Healy, 2007; Türkoğlu et al., 2009; Ateş, 2019).

3.7. Natural enemies: Bangasternus orientalis Capiomont (Coleoptera: Curculionidae)

Distribution in the world: Afghanistan, Armenia, Austria, Azerbaijan, Bulgaria, Central European Territory, Cyprus, Egypt, Georgia, Greece, Hungary, Italy, Jordan, Kazakhstan, North Macedonia, Romania, Russia, Slovakia, Southern Europe, Tajikistan and Turkey (Capiomont, 1873; Sert, 1995).

Distribution in Turkey: Adana, Ankara, Antalya, Aydın, Batman, Bilecik, Bitlis, Cankiri, Diyarbakir, Elazig, Eskisehir, Gaziantep, Hatay, Icel, Izmir, Kahramanmaras, Karabuk, Karaman, Kayseri, Kilis, Konya, Kırşehir, Manisa, Mardin, Mugla, Niğde, Osmaniye, Sivas, Trabzon, Yozgat (Lodos et al., 1978, 2003; Sert, 1995; Pehlivan et al., 2005; Erbey, 2010; Yılmaz, 2015). In the present study, *Bangasternus orientalis* was recorded as a new record for Hakkari Province insect fauna from Turkey (Fig. 3).

Material examined: Yüksekova basin Latitude-Longitude: 446663D-4145693K, 446709D-4144147K, 430363D-4157125K altitude, 1866–1950 m.

Recorded hosts: *Centaurea solstitialis* L. (Yellow starthistle) (Asteraceae) *Centaurea virgata* Lam. (Squarrose knapweed) (Asteraceae), *Centaurea iberica* Trev ex Sprengel (Iberian starthistle) (Asteraceae), *Centaurea calcitrapa* L. (Purple starthistle) (Asteraceae) (Ter-Minassian, 1978; Maddox et al., 1991; Gültekin, 2008; Anonymous, 2021a).

Host record: In the present study, *Centaurea iberica* was recorded as a host of *Bangasternus orientalis* from Hakkari/Turkey (Fig. 5).

Although the flora of Turkey is rich in Centaurea species, biological control studies are limited in the control of these species. In addition, any research conducted in Turkey on the biological control of *C. behen*, *C. iberica* and *C. ptercaula* species detected in the region has not been found in the literature. For this reason, determining biological control possibilities of these weed species has attracted the attention of researchers. In the study, although *C. iberica* was the most common species in the region, *Bangasternus orientalis* (Capiomont, 1873) was observed at only 3 locations feeding on the species. Similarly, *C. ptercaula* was one of the most widespread species in the region, *Larinus grisescens* feeding was observed in 3 locations. These two species spread in agricultural and grassland areas, it is suspected that the distribution and population density of insects may have been suppressed due to the mowing of weeds in these areas. Although the population density of *C. behen* was low in the region than the other two species, the densities of *Lixus pulverulentus* and *Larinus grisescens* species feeding on the plant and the number of feeding locations were higher.

4. Conclusion

Yüksekova Basin is an important phytogeographic region in terms of endemism due to its geographical location, topographic structure, and ecological factors. The region is in the "Iran-Turan Element", which further enriched its biological diversity. In addition, limited agricultural activities in the region and, more importantly, the almost non-existent use of chemical inputs has completely transformed the region into a natural ecosystem. For this reason, the investigation of weeds and natural enemies in the region suggests that it can help in the biological control of weeds that cause problems in agricultural areas and invasive weeds that become more widespread with global warming.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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